Arizona's Solar Market Analysis and Research Tool

Present and Future Cost of New Utility-Scale Electricity Generation

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Arizona's Solar Market Analysis and Research Tool (Az SMART)

Arizona's Solar Market Analysis and Research Tool (Az SMART) is a breakthrough analysis environment that will enable stakeholders to examine the complex interaction of economic, security, environmental, and technological issues that impact Arizona's ability to become a global leader in solar power innovation, development and deployment. Multi-disciplinary research efforts and capabilities at Arizona State University and the University of Arizona are being utilized in close collaboration with partners from industry and government in the creation and use of Az SMART.

The goal of the three-year project is to develop a unique analysis tool, tailored to the examination of a successful roll-out of large-scale solar energy infrastructure in Arizona, and the required electric grid technologies to enable that infrastructure.

The principal outputs of the project are Solar Feasibility research, a Solar Scorecard for Arizona, and ultimately, the analytical tool that integrates them into a decision support framework. The end product will be accessible by remote web access (www.azsmart.org), as well as at Decision Theater, a dynamic, immersive visualization environment facility at Arizona State University.

Arizona's Solar Scorecard

Researchers at the L. William Seidman Research Institute of the W. P. Carey School of Business at Arizona State University are developing Arizona's Solar Scorecard. The Solar Scorecard comprises metrics drawn from energy usage forecasts, environmental valuation analyses, economic development analyses, and energy security evaluations. It is assembled from a series of whitepapers which provide the research and analysis to translate commercial and public policy choices into measures of economic, environmental, social and energy security impact on Arizona. These papers will be completed over a three year span, with the first year largely concentrated on utility-scale power generation. The second and third years concentrate on distributed generation and transportation. The 14 whitepapers are as follows:

1. *Energy Sector Technology;*
2. *The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation;*
3. *Incentives and Taxation;*
4. *Regulations and Standards;*
5. *AZ Energy Demand Analysis;*
6. *Present and Future Cost of New Utility-Scale Electricity Generation;*
7. *Energy Usage/ Supply Forecasts;*
8. *Emissions/Pollution Analysis;*
9. *Solar Export Potential;*
10. *Environmental Valuation Analysis;*
11. *Solar Inter-State Competition;*
12. *Economic Development Analysis;*
13. *Energy Security Issues;*
14. *The Determinants of the Financial Return from Residential Photovoltaic Systems*

About This Paper

This white paper is an integration paper that combines the 2nd, 3rd, and 4th white papers out of the series of 14 white papers that make up the Solar Scorecard. The primary goal of this paper is to examine the levelized cost of utility-scale electricity generation taking into consideration current incentives available (at the federal and state level) as well as any form of possible carbon pricing. As Az SMART progresses the estimates contained within this paper will be refined to ensure that any additional government intervention that alters the generation costs across technologies are accounted for. Distributed forms of generation, and their financial cost characteristics, will be examined in a further paper.

Financial cost estimates are crucial when examining the economic impact of solar generation in research that forms part of the overall Solar Scorecard. It is important to note that this paper focuses exclusively on the financial costs associated with various forms of generation. Any environmental benefits/costs are set aside to be examined elsewhere. Financial costs estimated within this paper will provide an input to the estimation of the trade-offs that Arizona may face if it decides to invest in more solar generation.

Executive Summary

- There are a variety of technologies currently available to generate electricity. One of the major factors that determines a state's generation mix is cost. Market forces as well as government intervention will play a crucial role in determining Arizona's future generation mix.

- This paper builds upon the market-determined levelized costs previously calculated[1] as part of the Az SMART research program by incorporating government intervention into the market place by including significant financial incentives that are available for new renewable generation – such as the federal Investment Tax Credit (ITC) and carbon pricing.

- Once financial incentives that target renewable generation and carbon pricing are included the cost competitiveness of solar generation (as well as other forms of renewable generation) improves.

Government Intervention Examined/Incorporated into Analysis

- In the United States, the Investment Tax Credit[2] (ITC) is a federal corporate income tax credit for a portion of eligible expenditures related to investment in new renewable generation facilities. A 30 percent credit is available to entities in the commercial, industrial, and utility sectors for solar systems placed in service on or before December 31, 2016, thereafter, the credit becomes 10 percent.[3]

- When determining property taxes, renewable energy equipment that is owned by utilities and/or any other entities operating in Arizona is assessed at 20 percent of its depreciated cost. This renewable energy preferential property tax assessment was

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[1] See "*The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation", (2010)* Seidman Research Institute, available at www.azsmart.org.
[2] 26 USC § 48
[3] For other non-solar renewable technologies the credit and time frame varies, see "*Market Based Incentives" (2010)* Seidman Research Institute for more details.

originally set to expire in 2011. However it was recently extended (Arizona House Bill 2614) until December 31st, 2040.

- There are currently two indirect government mechanisms generally discussed when considering the pricing of carbon emissions, or more generally greenhouse gas (GHG) emissions: a Pigouvian tax and a cap and trade system. A cap-and-trade system is currently being debated at the federal level as part of the "Waxman-Markey bill". Both mechanisms essentially do the same thing, which is, impose an additional cost on those technologies that emit carbon, essentially raising the levelized cost of generation for technologies that use a carbon-based fuel.

- The investment tax credit and preferential property tax assessment that is available for numerous renewable technologies within Arizona, will reduce the capital cost component of the levelized cost estimates for renewable generation. On the other hand, carbon pricing, *if introduced,* will increase the levelized costs for those technologies that have relatively high heat rates and use a fuel which has relatively high carbon content. Overall both sets of mechanisms examined will impact solar in the same direction - namely improve the cost-competitiveness of solar generation technologies.

- The tables below present the levelized cost estimates per megawatt hour (MWh) once market alterations in the form of current investment tax credits and state-specific preferential property tax assessment rates are included. Then, the impact of carbon pricing being introduced as well as a potential extension in the ITC for solar technologies is explored and presented.

Utility-Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives Included

	2009		*2030*		
Technology[4]	**Reference[5]**	**Rising[6]**	**Reference[7]**	**Falling[8]**	**% Change (Ref.)**
Scrubbed New Coal	$103	$111	$95	$85	-8.6%
IGCC	$112	$116	$97	$86	-13.0%
IGCC with carbon seq.	$143	$144	$118	$102	-17.7%
Conv Gas/Oil Comb Cycle	$77	$108	$101	$97	30.9%
Adv Gas/Oil Comb Cycle (CC)	$76	$103	$97	$93	28.1%
Adv CC with carbon seq.	$101	$130	$119	$112	17.9%
Conv Comb Turbine	$84	$128	$124	$122	47.3%
Adv Comb Turbine	$78	$112	$108	$106	39.1%
Fuel Cells	$169	$216	$191	$176	13.1%
Adv Nuclear	$132	$143	$111	$93	-16.4%
Bio-mass	$120	$142	$115	$100	-4.1%
MSW - Landfill Gas	$117	$126	$110	$100	-5.6%
Geothermal	$79	$151	$120	$100	51.9%
Conventional Hydropower	$99	$113	$91	$71	-7.7%
Wind	$98	$143	$111	$91	12.8%
Wind Offshore	$176	$245	$185	$149	5.2%
Solar Thermal	$217	$248	$186	$148	-14.4%
Photovoltaic	$272	$323	$231	$175	-14.7%

[4] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

[5] Only the reference case is shown in 2009 as there is little difference between the cases.

[6] The *rising capital costs case* assumes that the cost adjustment factor is 25 percentage points higher than in the reference case between 2013 and 2030. Cost decreases due to learning can and do still occur. These cost reductions can partially or fully offset any cost factor increases, however for most technologies, costs in 2030 are *above* their 2008 levels (in the case of solar technologies they are marginally below their 2008 levels).

[7] In the EIA *reference case*, initial overnight costs for all technologies are updated to be consistent with costs estimates collected in early 2008. Changes in these overnight capital costs are driven by a cost adjustment factor, which is based on the projected producer price index for metals and metal product.

[8] The *falling plant capital costs case* assumes that overnight costs for the various generating technologies decreases at a faster rate than in the reference case, starting in 2013. By 2030, the cost adjustment factor is assumed to be 25 percentage points below its reference case value.

Utility-Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives and Carbon Price of $30 Included

	2009 Reference		*2030 Reference*	
Technology[9]	**Without Carbon Pricing**	**With Carbon Pricing**	**Without Carbon Pricing**	**With Carbon Pricing**
Scrubbed New Coal	$103	$129	$95	$119
IGCC	$112	$136	$97	$118
IGCC with carbon sequestration	$143	$146	$118	$120
Conv Gas/Oil Comb Cycle	$77	$89	$101	$112
Adv Gas/Oil Comb Cycle (CC)	$76	$86	$97	$107
Adv CC with carbon sequestration	$101	$102	$119	$120
Conv Comb Turbine	$84	$102	$124	$141
Adv Comb Turbine	$78	$93	$108	$122
Fuel Cells	$169	$181	$191	$202
Adv Nuclear	$132	$132	$111	$111
Bio-mass	$120	$120	$115	$115
MSW - Landfill Gas	$117	$134	$110	$127
Geothermal	$79	$87	$120	$127
Conventional Hydropower	$99	$99	$91	$91
Wind	$98	$98	$111	$111
Wind Offshore	$176	$176	$185	$185
Solar Thermal	$217	$217	$186	$186
Photovoltaic	$272	$272	$231	$231

[9] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

Utility-Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with the ITC remaining at 30 percent indefinitely and a Carbon Price of $30 Included

	2009 Reference		*2030 Reference*	
Technology[10]	**Without Carbon Pricing**	**With Carbon Pricing**	**Without Carbon Pricing**	**With Carbon Pricing**
Scrubbed New Coal	$103	$129	$95	$119
IGCC	$112	$136	$97	$118
IGCC with carbon sequestration	$143	$146	$118	$120
Conv Gas/Oil Comb Cycle	$77	$89	$101	$112
Adv Gas/Oil Comb Cycle (CC)	$76	$86	$97	$107
Adv CC with carbon sequestration	$101	$102	$119	$120
Conv Comb Turbine	$84	$102	$124	$141
Adv Comb Turbine	$78	$93	$108	$122
Fuel Cells	$169	$181	$191	$202
Adv Nuclear	$132	$132	$111	$111
Bio-mass	$120	$120	$115	$115
MSW - Landfill Gas	$117	$134	$110	$127
Geothermal	$79	$87	$120	$127
Conventional Hydropower	$99	$99	$91	$91
Wind	$98	$98	$111	$111
Wind Offshore	$176	$176	$185	$185
Solar Thermal	$217	$217	$157	$157
Photovoltaic	$272	$272	$189	$189

[10] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

The Cost Competitiveness of Solar

- The cost competitiveness of solar for the foreseeable future will be driven mainly by the amount of government intervention in the market place that will occur. Without government intervention it was previously shown that solar technologies would not be cost competitive without a significant deviation from currently forecast capital and fuel costs.[11]

Current Federal and State Incentives

- The levelized cost per MWh for solar thermal (photovoltaic) installed in 2009[12] are forecast to be $301 ($393) without government intervention whilst if current federal and state utility scale generation financial incentives are included the levelized costs in 2009 are $217 ($272).

- By 2030 the levelized cost per MWh for solar thermal (photovoltaic) are forecast to be $210 ($267) in the reference capital case and $165 ($201) in the falling capital case if there is no government intervention. If government intervention in incorporated then the levelized cost per MWh for solar thermal (photovoltaic) are forecast to be $186 ($231) in the reference capital case and $148 ($175) in the falling capital case.

- The reason why there is larger reduction in levelized costs per MWh occurring in 2009 when government intervention (both federal and state) are included than in 2030 is due to the timing of the legislation surrounding the federal investment tax credit. In 2017 the investment tax credit for solar is slated to fall to 10 percent from 30 percent.

- If it was assumed that the investment tax credit was kept at 30 percent for solar technologies *after* 2017 then the levelized cost per MWh for solar thermal (photovoltaic) are forecast to be $157 ($189) in the reference capital case and $127 ($145) in the falling capital case.

[11] See "*The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation", (2010)* Seidman Research Institute, available at www.azsmart.org

[12] 2009 was included so comparison and continuity with previous research ("*The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation", (2010)* Seidman Research Institute) was possible/maintained. As papers are updated the first year examined will also be updated.

- Assuming that the investment tax credit is extended past December 2016, solar technologies enjoy capital costs reductions consistent with the falling capital cost case assumed by the Energy Information Administration (EIA) and traditional sources of generation enjoy capital cost changes consistent with the rising capital cost case assumed by the EIA then solar technologies are forecast to be relatively cost competitive in 2030 against some natural gas generation technologies, nuclear, and technologies that have some form of carbon sequestration.[13]

Carbon Pricing

- The introduction of a carbon pricing of $30 improves the cost competitiveness of solar technologies. In fact, the impact of a $30 carbon price means that solar technologies will be competitive by 2030 with natural gas generation as long as the current federal ITC is extended beyond December 2016.

- The important result is that modest carbon pricing means that solar (especially solar thermal) will be cost competitive by 2030 with natural gas technologies without requiring all other traditional forms of generation to have a different cost trajectory (see the EIA rising capital cost case) whilst solar moves along the EIA falling capital cost case.

[13] In the rising capital cost case the levelized costs in 2030 are as follows: Conv Comb Turbine ($128), Nuclear ($143), IGCC with carbon sequestration ($144) and Adv CC with carbon sequestration ($130).

Carbon Pricing as a Tool to Achieve Grid-Parity

- If carbon pricing is introduced it increases the levelized costs of generation for fossil fuels. Thus, carbon pricing could be used as a mechanism to improve the time frame for which solar generation technologies achieve grid parity with traditional generation sources. The table below details the required carbon price per ton of carbon emitted that would be required for solar technologies to achieve grid parity by 2020 under various cost and ITC scenarios.

Required Carbon Pricing (2009$) for Solar to Achieve Grid Parity

	2020 Reference		*2020 Falling*	
	Expected ITC (10 Percent)	**ITC Maintained at 30 Percent**	**Expected ITC (10 Percent)**	**ITC Maintained at 30 Percent**
Solar Thermal Grid Parity				
Scrubbed New Coal	$155	$109	$134	$95
Conv Comb Turbine	$204	$137	$168	$109
Photovoltaic Grid Parity				
Scrubbed New Coal	$232	$166	$200	$141
Conv Comb Turbine	$320	$220	$264	$178

Remarks

- Any additional improvements (that are not actual capital cost reduction related) such as the federal and state financial incentives offered for solar generation, higher carbon pricing and/or fossil fuel prices, improved capacity factors for solar generation will further improve the cost competitiveness of solar as well as generate improvements in the timeframe with which solar generation achieves grid parity with other forms of generation.

- The potential introduction of carbon pricing creates another uncertainty, to go along with the uncertainty that already surrounds fuel costs, within the market place.

- If carbon pricing is finally introduced this will reduce some of the uncertainty – as planners now know that carbon is being priced. But a significant amount of uncertainty will still remain as it may potentially be difficult to predict the carbon price through time. Thus, this uncertainty (which is currently not incorporated into the levelized cost analysis) can only improve the attractiveness of solar as an electricity generating technology.[14]

[14] One feedback effect that is being ignored at the moment is the intermittency costs associated with solar technologies. Currently some of the intermittency costs associated with renewable technologies incorporate the need for natural gas to be available if solar output is not as expected. Thus any carbon pricing will inevitably cause the intermittency costs of solar to increase. This will be examined at a later date.

Table of Contents

Arizona's Solar Market Analysis and Research Tool (Az SMART) i
About This Paper iii
Executive Summary iv
List of Figures xv
List of Acronyms xvi
1. Introduction 1
2. Market-Determined Cost of New Generation 3
3. Government Intervention 7
3.1. Incentives 7
3.1.1 Federal Level Utility-Scale Generation: Investment Tax Credit 7
3.1.2. State Level Utility-Scale Generation Incentive: Preferential Property Tax Assessment 8
3.2. Regulations and Standards 9
3.3. Brief Overview of How Government Intervention Affects Levelized Costs 10
4. Levelized Cost Estimates with Government Intervention 11
4.1. Utility Scale Generation Levelized Costs Including Current Federal and State Incentives 11
4.2. New Utility Scale Generation Levelized Costs with Current Financial Incentives and Carbon Pricing Incorporated 18
4.2.1 Carbon Pricing Requirements for Solar to achieve Grid Parity by 2020 26
4.2.1.1 EIA Reference Capital Cost Scenario 26
4.2.1.2 EIA Falling Capital Cost Scenario 27
5. Conclusions 29
Glossary 31
Bibliography 32

List of Tables

Table 1: Utility Scale Levelized Cost per MWh of Electricity Delivered in 2009 and 2030 3
Table 2: Summary of the Current U.S. Investment Tax Credit 8
Table 3: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives Included 12
Table 4: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives and Carbon Price of $30 Included 19
Table 5: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with the ITC remaining at 30 percent and a Carbon Price of $30 Included 20
Table 6: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with the ITC remaining at 30 percent and a Carbon Price of $30 Included 21
Table 7: Required Carbon Pricing (2009$) for Solar to Achieve Grid Parity 28

List of Figures

Figure 1: Levelized Cost of Delivered Electricity 2009: Reference Case 4
Figure 2: Levelized Cost of Delivered Electricity 2030: Reference Case 5
Figure 3: Key Determinants in Levelized Cost Analysis with Government Intervention........ 10
Figure 4: Levelized Cost of Delivered Electricity 2009: Reference Case with Government Intervention........ 14
Figure 5: Levelized Cost of Delivered Electricity 2030: Reference Case with Government Intervention........ 15
Figure 6: Levelized Cost of Delivered Electricity 2030: Falling Case with Government Intervention........ 16
Figure 7: Levelized Cost of Delivered Electricity 2009: Reference Case with Current State and Federal Incentives and Carbon Pricing........ 22
Figure 8: Levelized Cost of Delivered Electricity 2030: Reference Case with Current State and Federal Incentives and Carbon Pricing........ 23
Figure 9: Levelized Cost of Delivered Electricity 2030: Reference Case assuming ITC remains at 30 Percent and Carbon Pricing........ 24
Figure 10: Levelized Cost of Delivered Electricity 2030: Falling Case assuming ITC remains at 30 Percent and Carbon Pricing........ 25

List of Acronyms

Abbreviation	*Definition*
Entities	
APS	Arizona Public Service Company
CPUC	California Public Utilities Commission
DSIRE	Database of State Incentives for Renewable Energy
EIA	Energy Information Administration
NREL	National Renewable Energy Laboratory
Other Terms	
Btu	British thermal units
GHG	Greenhouse Gas
GWh	Gigawatt hours
HVAC	Heating, ventilating and air conditioning
ITC	Investment Tax Credit
kW	Kilowatt
kWh	kilowatt hour
LCOE	Levelized cost of electricity
MW	Megawatt
MWh	Megawatt hour
O&M	Operations and maintenance
PV	Photovoltaic
RES	Renewable energy standard
RPS	Renewable Portfolio Standard
T&D	Transmission and Distribution

1. Introduction

There are a variety of technologies currently available to generate electricity. One of the major factors that determines a state's generation mix is cost. Market forces as well as government intervention play a role in determining costs and thus Arizona's future generation mix.

The objective of this paper is to estimate the levelized cost of generation of various generation technologies that are available now and/or will be in the foreseeable future. These levelized costs incorporate various incentive and taxation schemes (carbon pricing) that are currently instituted by the government (federal and state) and/or being discussed that attempt to alter the relative cost of electricity generation across technologies.

The various government-imposed incentive and taxation schemes will impact the financial costs of each generation technology differently. For instance, carbon pricing, if introduced, will increase the levelized cost of coal-fired generation technologies more than the levelized cost of natural gas generation technologies due to the higher heat rates and carbon content associated with coal generation.

The focus of this paper is government schemes that alter the financial cost of the various generation technologies. Thus schemes indirectly affect a utilities decision making with regards to new generation deployment. Other government schemes also influence choice of generation technology. For instance, regulated utilities in Arizona are required to meet 15 percent of their electricity sales in 2025 using renewable generation methods.[15]

Clearly, for regulated utilities the decision of when to install or purchase renewable generation, or at least the last date by which renewable generation needs to be in place, is potentially determined more by direct mechanisms (renewable portfolio standard for instance) than by indirect mechanisms that adjust the relative financial cost of renewable generation versus traditional generation technologies. System integrity, location constraints, proximity to load pockets, potential intermittency issues, water usage, other environmental concerns, access to

[15] Database of State Incentives for Renewables & Efficiency (DSIRE)

fuel supplies, are further considerations that ultimately determine generation mixes for utilities.[16]

The structure of the paper is as follows. Section 2 discusses the market-determined costs of generation previously derived. Section 3 provides an overview of the key government introduced schemes that are incorporated into the levelized cost analysis. Section 4 contains our levelized cost forecasts. Section 5 provides some conclusions.

[16] All of which (and wider social considerations - economic development for example) will be examined as part of the "Solar Scorecard".

2. Market-Determined Cost of New Generation

Previous estimates provided by the Seidman Research Institute (all costs are in 2009$) of the market-determined levelized cost for each generation technology, under various capital cost assumptions, are presented for the years 2009 and 2030 in Table 1 and Figures 1 and 2.[17]

Table 1: Utility Scale Levelized Cost per MWh of Electricity Delivered in 2009 and 2030

	2009		*2030*		
Technology	**Reference[18]**	**Rising**	**Reference**	**Falling**	**% Change (Ref.)**
Scrubbed New Coal	$102	$112	$96	$86	-5.9%
IGCC	$111	$118	$99	$87	-10.8%
IGCC with carbon sequestration	$141	$144	$117	$101	-17.2%
Conv Gas/Oil Comb Cycle	$105	$125	$119	$115	13.5%
Adv Gas/Oil Comb Cycle (CC)	$101	$119	$113	$109	11.8%
Adv CC with carbon sequestration	$133	$149	$138	$131	3.5%
Conv Comb Turbine	$125	$155	$150	$148	20.3%
Adv Comb Turbine	$113	$133	$130	$128	15.1%
Fuel Cells	$228	$239	$212	$196	-7.0%
Adv Nuclear	$132	$144	$111	$93	-16.0%
Bio-mass	$148	$148	$120	$104	-19.1%
MSW - Landfill Gas	$119	$130	$113	$103	-5.4%
Geothermal	$92	$169	$133	$108	43.8%
Conventional Hydropower	$103	$118	$96	$74	-7.4%
Wind	$127	$150	$116	$95	-9.0%
Wind Offshore	$227	$246	$186	$150	-17.8%
Solar Thermal	$301	$283	$210	$165	-30.3%
Photovoltaic	$393	$375	$267	$201	-32.0%

Source: "The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation", (2010) Seidman Research Institute

[17] See "*The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation*", *(2010)* Seidman Research Institute, available at www.azsmart.org for more details on how the levelized costs were derived.
[18] Only the reference case is shown in 2009 as there is little difference between the cases.

Figure 1: Levelized Cost of Delivered Electricity 2009: Reference Case

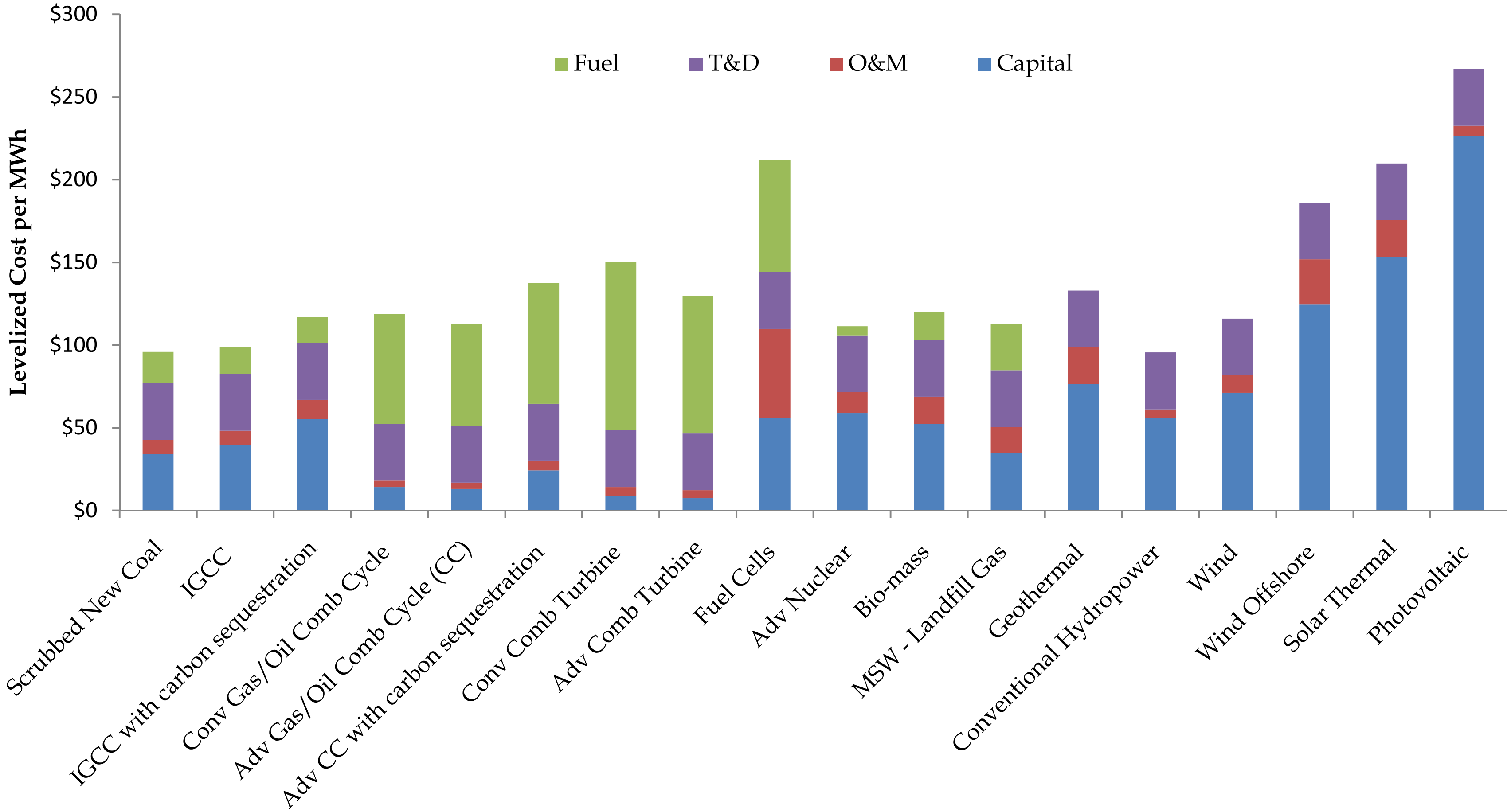
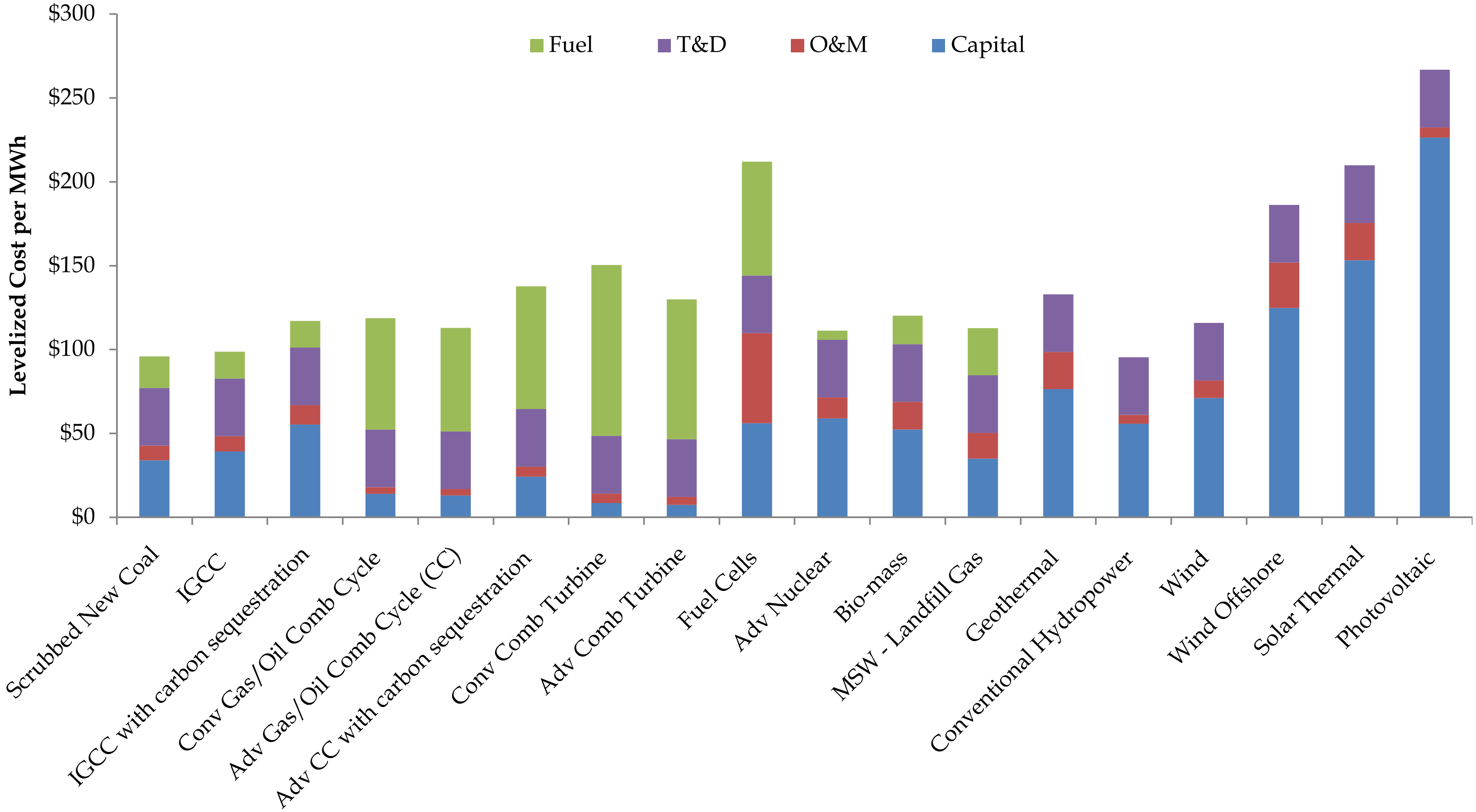


Figure 2: Levelized Cost of Delivered Electricity 2030: Reference Case



Examining Table 1, if significant capital cost reductions (falling capital cost) occur for solar generation then the market-determined levelized cost per MWh in 2030 for solar thermal is $165 and for PV it is $201. If we assume rising capital costs for traditional generation all traditional resources have a levelized cost ranging from $112 (scrubbed coal) to $155 (gas conventional combustion turbine).[19]

Even if solar generation enjoys significant *reductions* in capital costs (45-59 percent) whilst traditional generation face *increasing* capital costs (1-23 percent) traditional generation still remains more competitive in 2030 if there is no government intervention and assuming no significant deviation from forecast cost trends.

For solar thermal to achieve a levelized cost of $155 per MWh in 2030 its overnight capital cost per KW would need to be approximately $2,100 (2009$) whilst PV overnight capital costs per KW would have to be approximately $1,960 (2009$). These capital costs represent reductions of 58 percent and 67 percent relative to the reference capital cost case in 2009.

High capacity factor wind generation[20] initially appears to be competitive against some traditional resources (mainly gas and nuclear). However, some caution must be exercised, as the analysis has not yet incorporated the additional costs of integration and transmission.[21] Also, the amount of high capacity factor wind in Arizona is limited.[22]

The estimates above provide some stark indications. Without significant deviations away from the expected future values of key cost inputs such as capital and fuel costs or some form of government intervention that *lowers* the financial cost of solar thermal and utility-scale PV systems (for example an investment tax credit) or *raises* the financial cost of traditional forms of generation (for example carbon pricing), solar is not cost-competitive against other traditional generation resources for numerous years.

[19] Assuming a natural gas fuel cost of 9.75 cents (2009$) per million BTU.
[20] In Arizona the "high capacity factor wind" is approximately 35 percent.
[21] For instance, in Beck, (2009) their integration costs may vary from approximately $1-$4 per MWh depending upon the amount of wind penetration.
[22] See Black and Veatch, (2007).

3. Government Intervention

There are numerous policy interventions available to the government (at all levels of government, federal, state and local) that can assist with adjusting the cost of generation for the various generation technologies. Below is a brief discussion surrounding the major schemes[23] in place, or that are currently being discussed, that are incorporated into our levelized cost analysis that follows.

3.1. Incentives

The discussion below contains information on the current utility-scale financial incentives that target renewable, with a focus on solar, generation offered at the federal and state level.[24]

3.1.1 Federal Level Utility-Scale Generation: Investment Tax Credit

In the United States, the Investment Tax Credit[25] (ITC) is a federal corporate income tax credit for a portion of eligible expenditures related to investment in new renewable generation facilities. The credit is available to entities in the commercial, industrial, and utility sectors for systems placed in service on or before December 31, 2016. The amount of the credit varies with each technology, as summarized in the following table:

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[23] By major we mean the schemes or programs that will ultimately have the largest impact on levelized costs per MWh.

[24] For more details on the various incentives offered within the United States and the rest of the world See *"Market Based Incentives" (2010)* Seidman Research Institute, available at www.azsmart.org.

[25] 26 USC § 48

Table 2: Summary of the Current U.S. Investment Tax Credit

Federal Investment Tax Credit			
Renewable resource	**Eligibility restrictions**	**In-service deadline**	**% of expenses eligible for credit**
Solar	Excludes passive solar and solar pool-heating systems	12/31/2016	30% (10% thereafter)
Fuel cells	0.5 kW minimum capacity 30% minimum efficiency		30%
Wind		12/31/2012	30%
Geothermal power	For energy production, applies to equipment used in all stages prior to transmission For geothermal heat pumps, applies to pumps and equipment used to produce, distribute, or use energy derived from a geothermal deposit	12/31/2013 for the 30% credit; none for the 10% credit	10% - 30%
Microturbines	2 MW maximum capacity 26% minimum efficiency		10%, up to $200/kW of capacity
CHP	50 MW maximum capacity 60% minimum efficiency for systems that use less than 90% biomass	12/31/2013	30%

Source: "Market Based Incentives" (2010) Seidman Research Institute

3.1.2. State Level Utility-Scale Generation Incentive: Preferential Property Tax Assessment

When determining property taxes, renewable energy equipment that is owned by utilities and/or any other entities operating in Arizona is assessed at 20 percent of its depreciated cost. Renewable energy equipment is defined as "electric generation facilities, electric transmission, electric distribution, gas distribution or combination gas and electric transmission and distribution and transmission and distribution cooperative property that is located in this state, that is used or useful for the generation, storage, transmission or distribution of electric power, energy or fuel derived from solar, wind or other nonpetroleum renewable sources not intended for self-consumption, including materials and supplies and construction work in progress."[26]

This renewable energy preferential property tax assessment was originally set to expire in 2011. However it was recently extended (Arizona House Bill 2614) until December 31st, 2040.

[26] DSIRE

3.2. Regulations and Standards

There are currently two indirect government mechanisms often discussed to price carbon emissions, or more generally, greenhouse gas (GHG) emissions: a Pigouvian tax and a cap and trade system.[27] A cap-and-trade system is currently being debated at the federal level as part of the "Waxman-Markey bill". Both mechanisms essentially do the same thing which is impose a cost on those technologies that emit carbon. This essentially will raise the levelized cost of generation for technologies that use a fuel that has a carbon content.[28]

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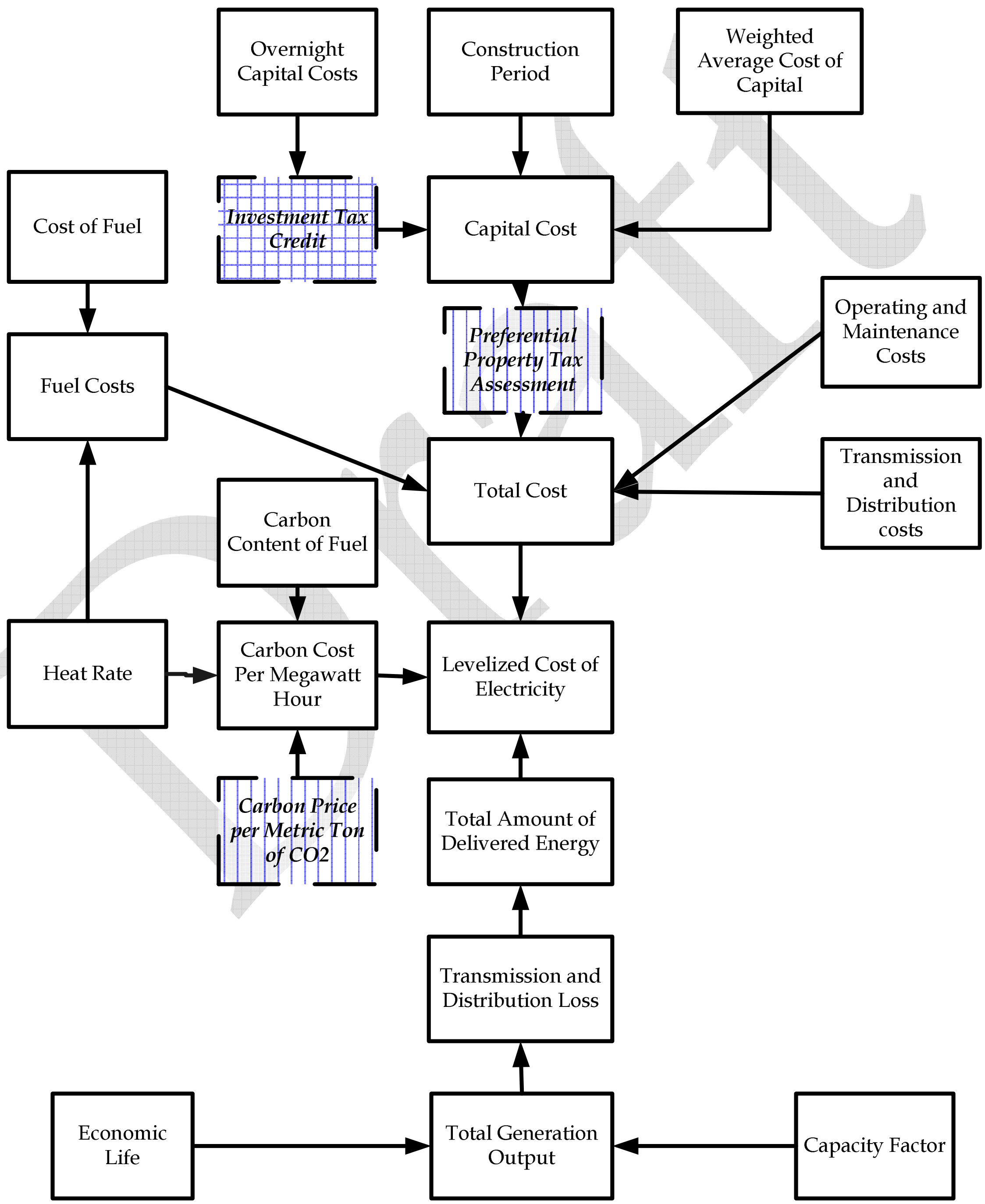
[27] The focus here is on government regulation and standards that *alter* the levelized costs per MWh generated rather than policies like renewable energy portfolios that have no effect on levelized costs but rather alter the overall decision making process with regards to what types of technologies can be deployed and when.

[28] For more details and discussion see Seidman Research Institute (2010). *"Regulations and Standards: Part I"*.

3.3. Brief Overview of How Government Intervention Affects Levelized Costs

Figure 3 below re-produces the key inputs that ultimately determine the levelized costs of generation but now with some key government intervention being incorporated.

Figure 3: Key Determinants in Levelized Cost Analysis with Government Intervention



The investment tax credit and preferential property tax assessment that is available for numerous renewable technologies will reduce the capital cost component of the levelized cost analysis for those technologies.[29]

Further, the carbon pricing, *if introduced*, will increase the levelized costs for those technologies that have relatively high heat rates and use a fuel which has relatively high carbon content.

4. Levelized Cost Estimates with Government Intervention

The results presented below incorporate the government schemes outlined in Section 3. First, the investment tax credit (federal incentive) and the reduced property tax assessment rate (state incentive) are included – with a focus on how these incentives affect the levelized cost of solar technologies Then an illustration of how carbon pricing will alter the levelized cost of generation is also incorporated.[30]

4.1. Utility Scale Generation Levelized Costs Including Current Federal and State Incentives

It is important to note that the levelized costs per MWh below are the levelized costs to *deliver* generated electricity to customers. Thus transmission losses and transmission and distribution costs are also included. This is done to remain consistent with the market-determined estimates described in Section 2.[31]

[29] Note, it is no co-incidence that a major government scheme to improve the cost-competitiveness of renewable is an ITC as the majority of renewable technologies are capital intensive, thus an ITC - which lowers the capital costs incurred - is a scheme that will assist with lowering levelized costs.
[30] It is beyond the scope of this paper to estimate what the carbon price would be if indeed carbon pricing is introduced sometime in the future.
[31] The levelized costs of just generation are available upon request.

Table 3: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives Included

	2009	*2030*			
Technology[32]	**Reference[33]**	**Rising[34]**	**Reference[35]**	**Falling[36]**	**% Change (Ref.)**
Scrubbed New Coal	$103	$111	$95	$85	-8.6%
IGCC	$112	$116	$97	$86	-13.0%
IGCC with carbon seq	$143	$144	$118	$102	-17.7%
Conv Gas/Oil Comb Cycle	$77	$108	$101	$97	30.9%
Adv Gas/Oil Comb Cycle (CC)	$76	$103	$97	$93	28.1%
Adv CC with carbon seq	$101	$130	$119	$112	17.9%
Conv Comb Turbine	$84	$128	$124	$122	47.3%
Adv Comb Turbine	$78	$112	$108	$106	39.1%
Fuel Cells	$169	$216	$191	$176	13.1%
Adv Nuclear	$132	$143	$111	$93	-16.4%
Bio-mass	$120	$142	$115	$100	-4.1%
MSW - Landfill Gas	$117	$126	$110	$100	-5.6%
Geothermal	$79	$151	$120	$100	51.9%
Conventional Hydropower	$99	$113	$91	$71	-7.7%
Wind	$98	$143	$111	$91	12.8%
Wind Offshore	$176	$245	$185	$149	5.2%
Solar Thermal	$217	$248	$186	$148	-14.4%
Photovoltaic	$272	$323	$231	$175	-14.7%

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[32] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

[33] Only the reference case is shown in 2009 as there is little difference between the cases.

[34] The *rising capital costs case* assumes that the cost adjustment factor is 25 percentage points higher than in the reference case between 2013 and 2030. Cost decreases due to learning can and do still occur. These cost reductions can partially or fully offset any cost factor increases, however for most technologies, costs in 2030 are *above* their 2008 levels (in the case of solar technologies they are marginally below their 2008 levels).

[35] In the EIA *reference case*, initial overnight costs for all technologies are updated to be consistent with costs estimates collected in early 2008. Changes in these overnight capital costs are driven by a cost adjustment factor, which is based on the projected producer price index for metals and metal product.

[36] The *falling plant capital costs case* assumes that overnight costs for the various generating technologies decreases at a faster rate than in the reference case, starting in 2013. By 2030, the cost adjustment factor is assumed to be 25 percentage points below its reference case value.

Examining Table 2 and focusing on the solar technologies, it can be seen that the ITC and the reduced property tax assessment value do assist with reducing the levelized costs for solar thermal and photovoltaic generation.

Figures 4, 5 and 6 depict the disaggregation (capital costs, operations and maintenance, fuel costs and transmission and distribution costs components) of the levelized cost per MWh for the various technologies in 2009 and 2030 for the reference capital cost case and in 2030 for the falling capital cost case.

It is apparent from the figures that the major reason for solar technologies lacking cost-competitiveness relative to traditional generation sources is due to its overall capital intensive nature which, coupled with its reduced capacity factor relative to traditional generation sources, causes the capital cost component of its levelized cost to be significantly high.

Figure 4: Levelized Cost of Delivered Electricity 2009: Reference Case with Government Intervention

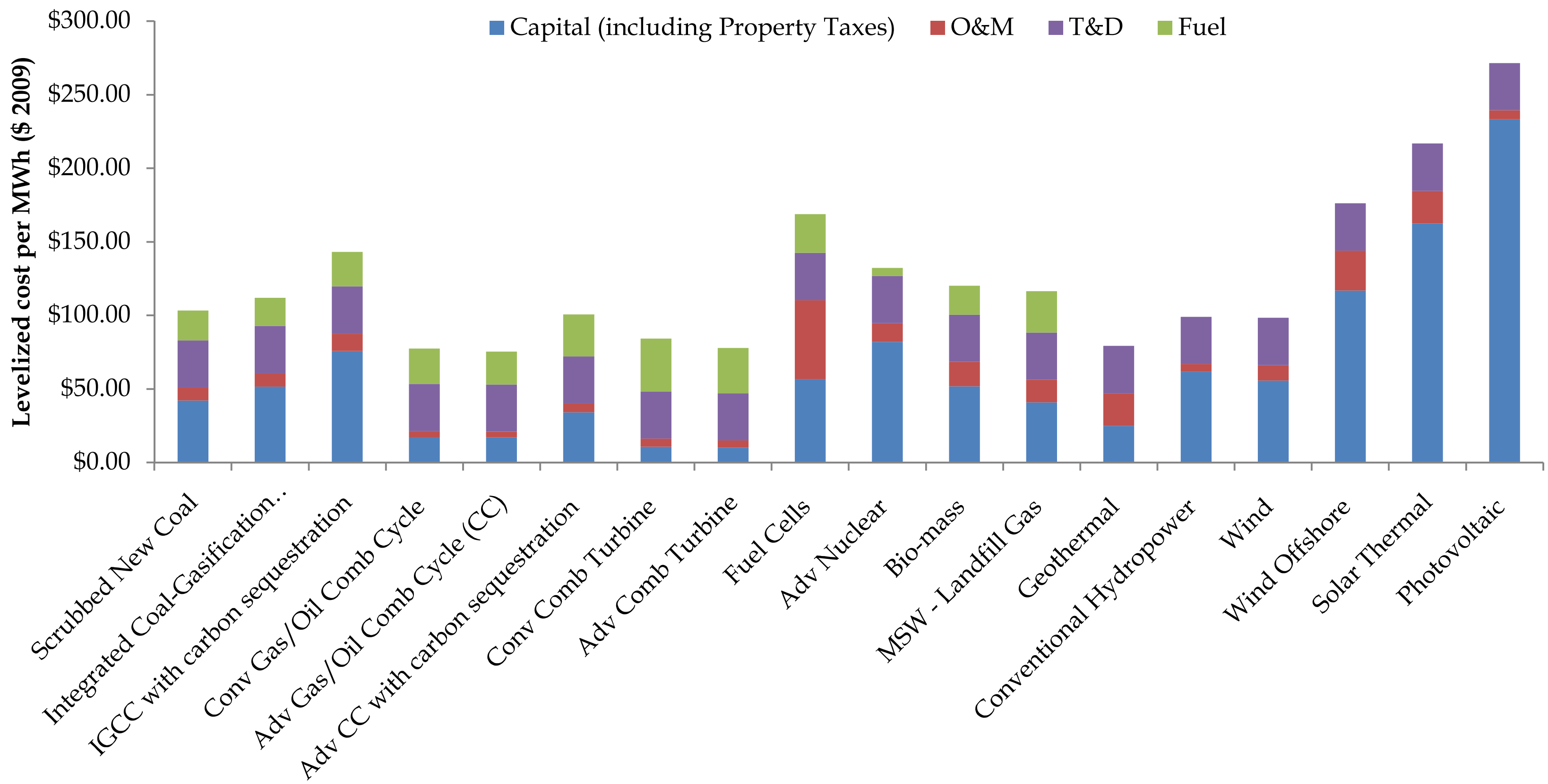


Figure 5: Levelized Cost of Delivered Electricity 2030: Reference Case with Government Intervention

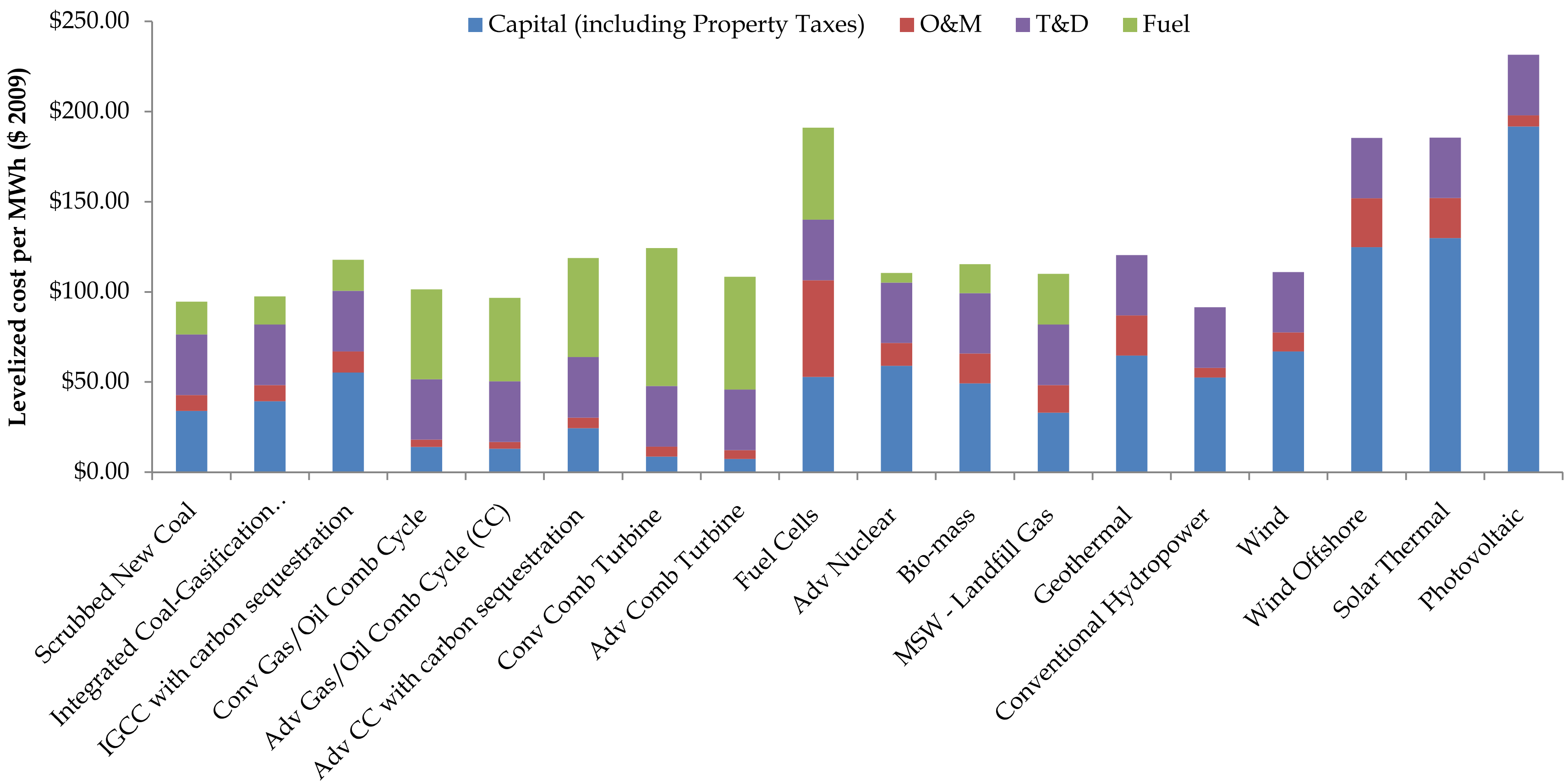
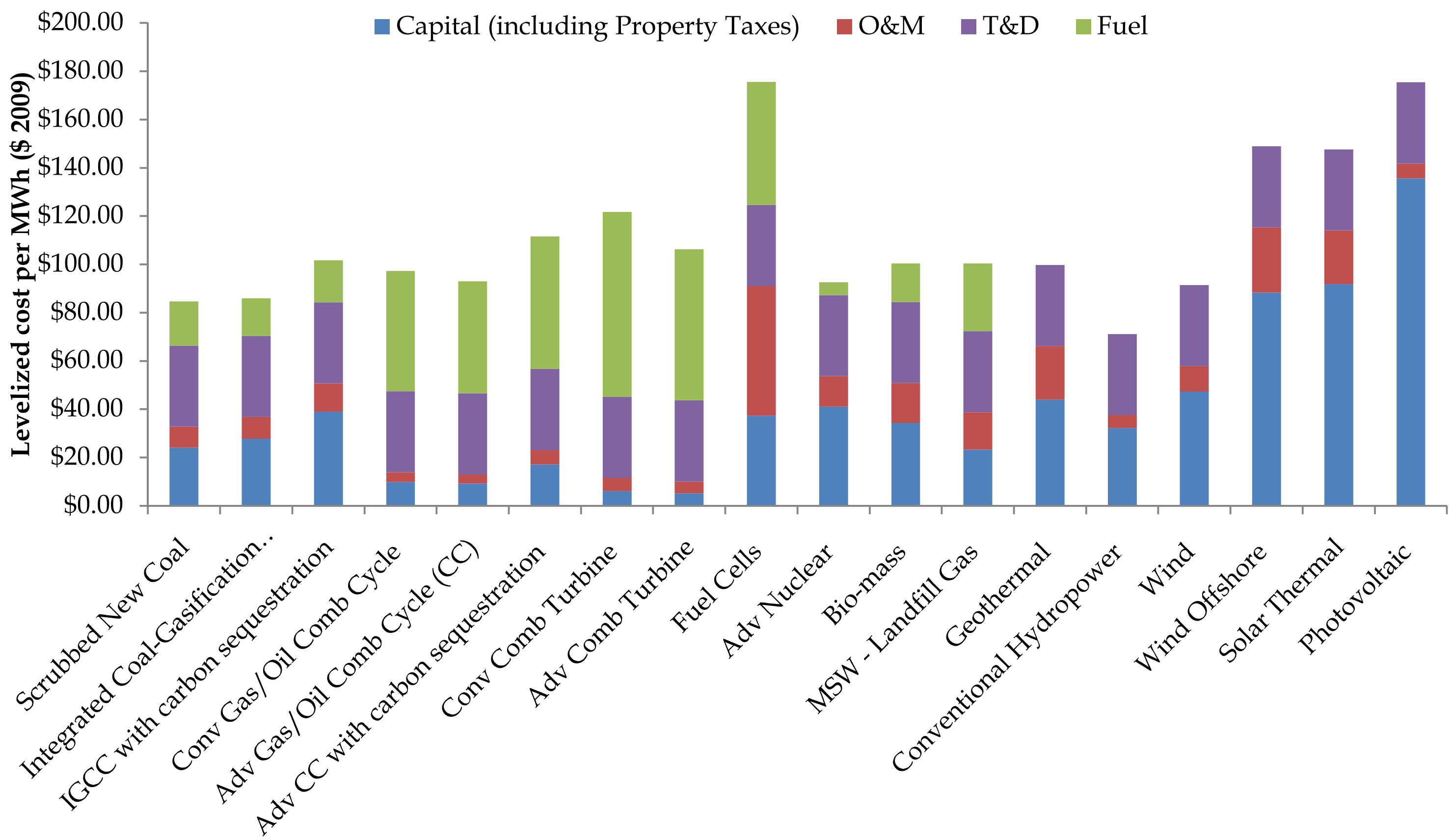


Figure 6: Levelized Cost of Delivered Electricity 2030: Falling Case with Government Intervention



Comparing the results in Table 2 and Table 1 the levelized cost for solar thermal (photovoltaic) installed in 2009 were $301 ($393) without government intervention whilst with government intervention in the form of financial incentives the levelized costs per MWh in 2009 are $217 ($272).

By 2030 the levelized cost for solar thermal (photovoltaic) are forecast to be $210 ($267) in the EIA reference capital case and $165 ($201) in the EIA falling capital case if there is no government intervention. If there is government intervention the levelized cost per MWh for solar thermal (photovoltaic) are forecast to be $186 ($231) in the EIA reference capital case and $148 ($175) in the EIA falling capital case.

The reason why there is a larger reduction in levelized costs per MWh occurring in 2009 when government intervention (both federal and state) are included than in 2030 is due to the timing of the legislation surrounding the federal investment tax credit. In 2017 the investment tax credit for solar will fall to 10 percent from 30 percent.

If the investment tax credit was kept at 30 percent for solar technologies after 2017 then the levelized cost per MWh for solar thermal (photovoltaic) are forecast to be $157 ($189) in the reference capital case and $127 ($145) in the falling capital case.

In summary, assuming the investment tax credit is extended past December 2016, solar technologies will enjoy capital costs reductions consistent with the falling capital cost case assumed by the EIA and traditional sources of generation enjoy capital cost reductions consistent with the rising capital cost case assumed by the EIA then solar thermal will be relatively cost competitive in 2030 against some natural gas technologies, nuclear, and technologies that have some form of carbon sequestration.[37]

[37] In the rising capital cost case the levelized costs in 2030 are as follows: Conv Comb Turbine ($128), Nuclear ($143), IGCC with carbon sequestration ($144) and Adv CC with carbon sequestration ($130).

4.2. New Utility Scale Generation Levelized Costs with Current Financial Incentives and Carbon Pricing Incorporated

As noted, there is a growing probability that some mechanism will be introduced to price carbon emission in the foreseeable future.[38] By introducing a price for carbon emissions, typically the price is expressed as a dollar amount per metric ton of CO_2 emitted, a rise in the levelized costs for generation technologies that use carbon emitting fuels will occur.

The technologies that have the highest heat rates (need to burn more fuel to generate a megawatt hour of electricity) and/or use fuels that contain a higher carbon content (coal is the fuel with the highest carbon content per BTU) will face a larger increase in their levelized costs. Technologies that have some form of carbon sequestration will be able to avoid some of the carbon emissions payments.

It is important to note that through time the EIA assumes that newly built generation plants that use fossil fuels will have improved heat rates. Therefore, even if the real carbon price remains constant, the increase in levelized costs caused by the introduction of carbon pricing will fall through time.

Thus, the introduction of carbon pricing will benefit (through improving their cost competitiveness) those technologies that do not emit carbon, namely most renewable technologies and nuclear.[39]

Table 3,4 and 5 as well as Figures 7,8,9 and 10 below provide illustrations of how the levelized cost estimates across technologies may vary if a (real) carbon price of $30[40] (2009$) per metric

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[38] The most often discussed mechanisms are a cap-and-trade program and a carbon tax.

[39] Note, we are focusing on the carbon content created at the point of electricity generation and, for the time being, ignoring the carbon "footprint" of constructing the various generating facilities. This will be examined in a future paper.

[40] $30 per metric ton was chosen for illustrative purposes. It is also approximately the figure the Congressional Budget Office (CBO) has estimated (See "*The Estimated Costs to Households From the Cap-and-Trade Provisions of H.R. 2454*", CBO (2009)) may occur in 2020 if Waxman-Markey passes.

ton is introduced under various assumptions around the capital cost reductions that may occur and if the 30 percent federal solar ITC is extend beyond December 2016.

Table 4: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with Current Federal and State Financial Incentives and Carbon Price of $30 Included

	2009 Reference		*2030 Reference*	
Technology[41]	**Without Carbon Pricing**	**With Carbon Pricing**	**Without Carbon Pricing**	**With Carbon Pricing**
Scrubbed New Coal	$103	$129	$95	$119
IGCC	$112	$136	$97	$118
IGCC with carbon sequestration	$143	$146	$118	$120
Conv Gas/Oil Comb Cycle	$77	$89	$101	$112
Adv Gas/Oil Comb Cycle (CC)	$76	$86	$97	$107
Adv CC with carbon sequestration	$101	$102	$119	$120
Conv Comb Turbine	$84	$102	$124	$141
Adv Comb Turbine	$78	$93	$108	$122
Fuel Cells	$169	$181	$191	$202
Adv Nuclear	$132	$132	$111	$111
Bio-mass	$120	$120	$115	$115
MSW - Landfill Gas	$117	$134	$110	$127
Geothermal	$79	$87	$120	$127
Conventional Hydropower	$99	$99	$91	$91
Wind	$98	$98	$111	$111
Wind Offshore	$176	$176	$185	$185
Solar Thermal	$217	$217	$186	$186
Photovoltaic	$272	$272	$231	$231

[41] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

Table 5: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with the ITC remaining at 30 percent and a Carbon Price of $30 Included

	2009 Reference		*2030 Reference*	
Technology[42]	**Without Carbon Pricing**	**With Carbon Pricing**	**Without Carbon Pricing**	**With Carbon Pricing**
Scrubbed New Coal	$103	$129	$95	$119
IGCC	$112	$136	$97	$118
IGCC with carbon sequestration	$143	$146	$118	$120
Conv Gas/Oil Comb Cycle	$77	$89	$101	$112
Adv Gas/Oil Comb Cycle (CC)	$76	$86	$97	$107
Adv CC with carbon sequestration	$101	$102	$119	$120
Conv Comb Turbine	$84	$102	$124	$141
Adv Comb Turbine	$78	$93	$108	$122
Fuel Cells	$169	$181	$191	$202
Adv Nuclear	$132	$132	$111	$111
Bio-mass	$120	$120	$115	$115
MSW - Landfill Gas	$117	$134	$110	$127
Geothermal	$79	$87	$120	$127
Conventional Hydropower	$99	$99	$91	$91
Wind	$98	$98	$111	$111
Wind Offshore	$176	$176	$185	$185
Solar Thermal	$217	$217	$157	$157
Photovoltaic	$272	$272	$189	$189

[42] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

Table 6: Utility Scale Levelized Cost per MWh (2009$) of Electricity Delivered in 2009 and 2030 with the ITC remaining at 30 percent and a Carbon Price of $30 Included

	2009 Falling		*2030 Falling*	
Technology[43]	**Without Carbon Pricing**	**With Carbon Pricing**	**Without Carbon Pricing**	**With Carbon Pricing**
Scrubbed New Coal	$103	$129	$85	$109
IGCC	$112	$136	$86	$107
IGCC with carbon sequestration	$143	$146	$102	$104
Conv Gas/Oil Comb Cycle	$77	$89	$97	$108
Adv Gas/Oil Comb Cycle (CC)	$75	$86	$93	$103
Adv CC with carbon sequestration	$101	$102	$112	$113
Conv Comb Turbine	$84	$101	$122	$138
Adv Comb Turbine	$78	$93	$106	$120
Fuel Cells	$169	$181	$176	$187
Adv Nuclear	$132	$132	$93	$93
Bio-mass	$120	$120	$100	$100
MSW - Landfill Gas	$116	$133	$100	$117
Geothermal	$79	$87	$100	$107
Conventional Hydropower	$99	$99	$71	$71
Wind	$98	$98	$91	$91
Wind Offshore	$176	$176	$149	$149
Solar Thermal	$216	$216	$127	$127
Photovoltaic	$270	$270	$145	$145

[43] The EIA recently released up-dated coal and natural gas price forecasts which have been incorporated in this analysis. Thus some technologies that are not impacted by the ITC and preferential property tax assessment will still have a change in levelized costs to those previously estimates – generally in a downwards direction.

Figure 7: Levelized Cost of Delivered Electricity 2009: Reference Case with Current State and Federal Incentives and Carbon Pricing

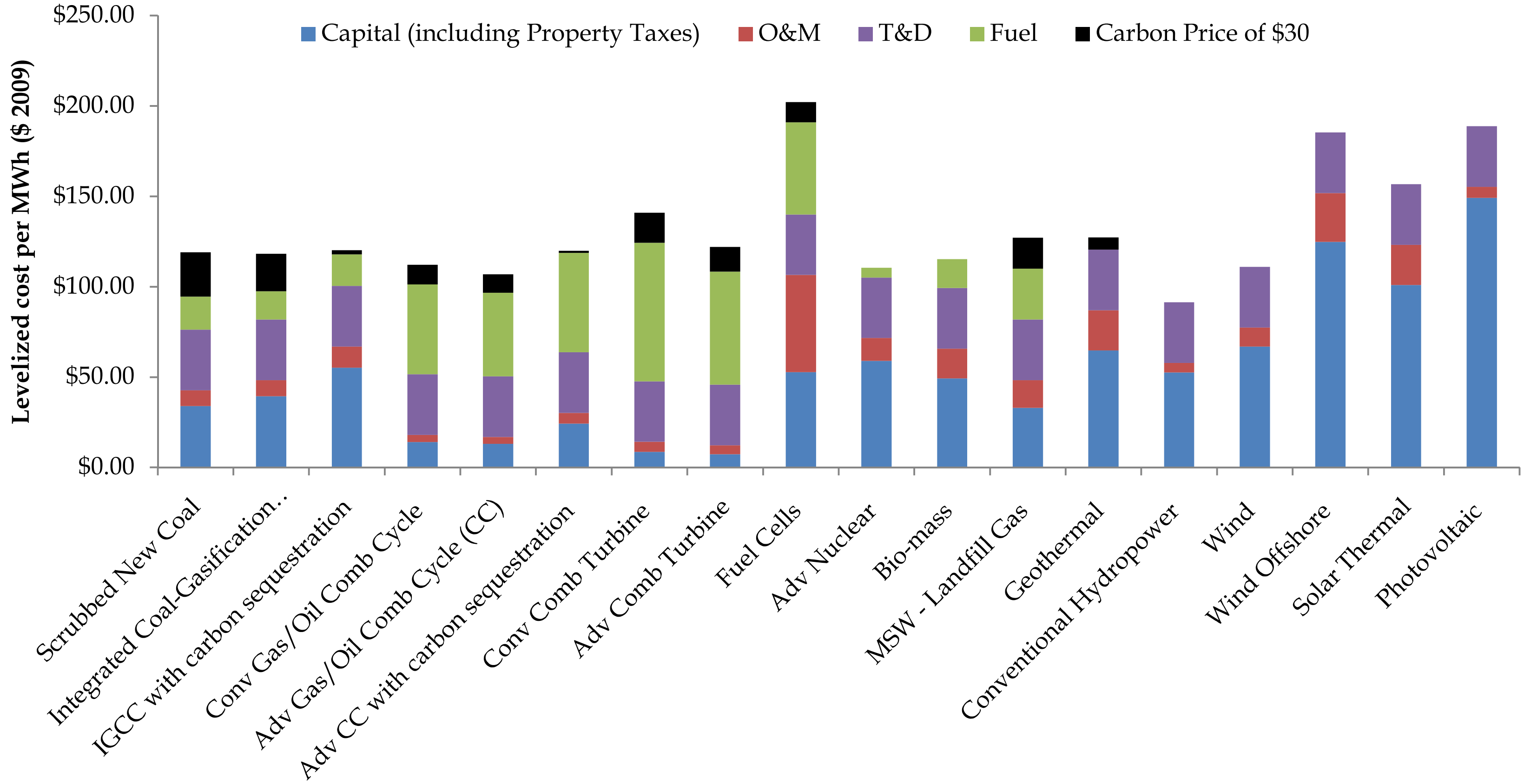


Figure 8: Levelized Cost of Delivered Electricity 2030: Reference Case with Current State and Federal Incentives and Carbon Pricing

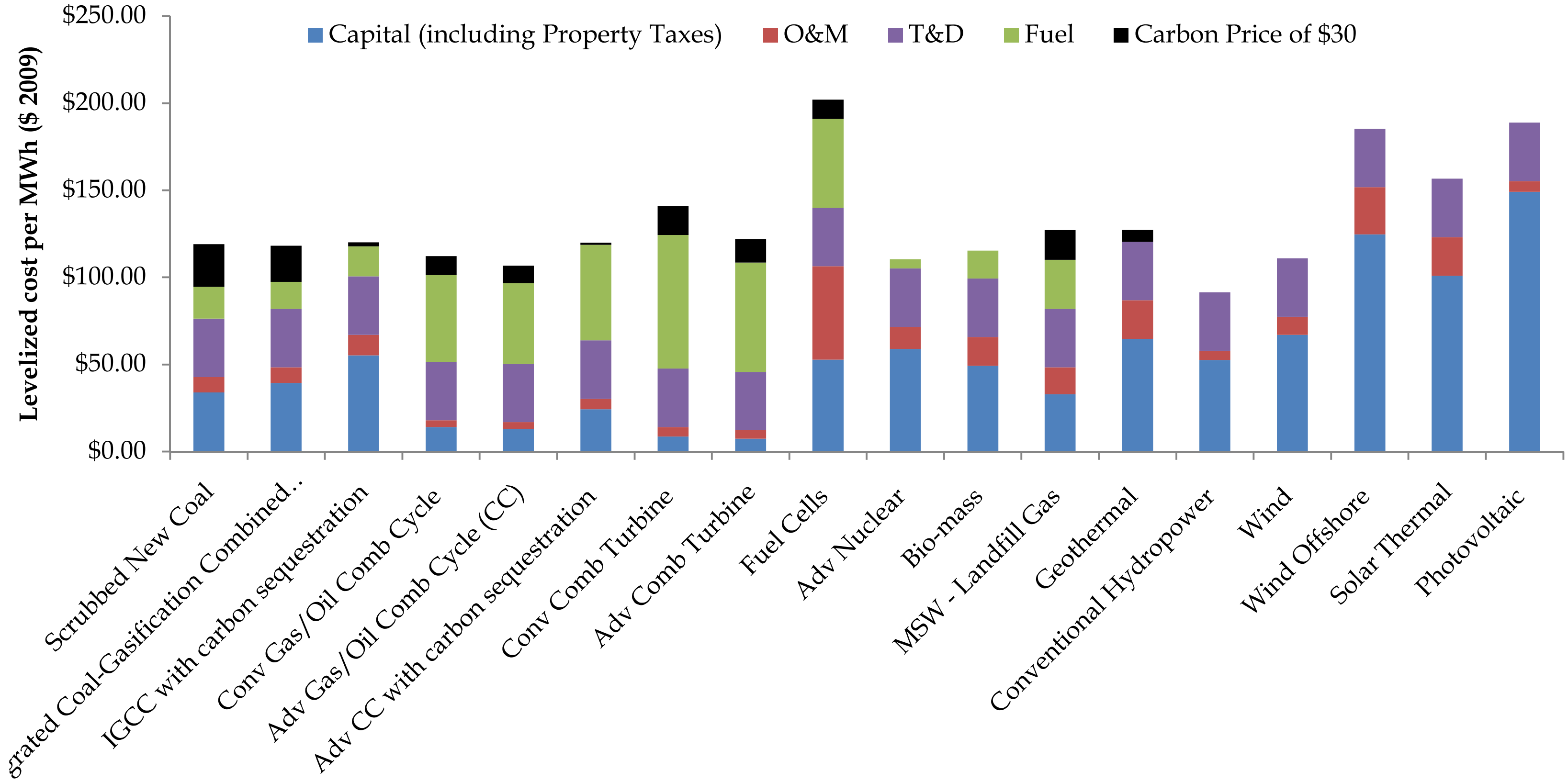


Figure 9: Levelized Cost of Delivered Electricity 2030: Reference Case assuming ITC remains at 30 Percent and Carbon Pricing

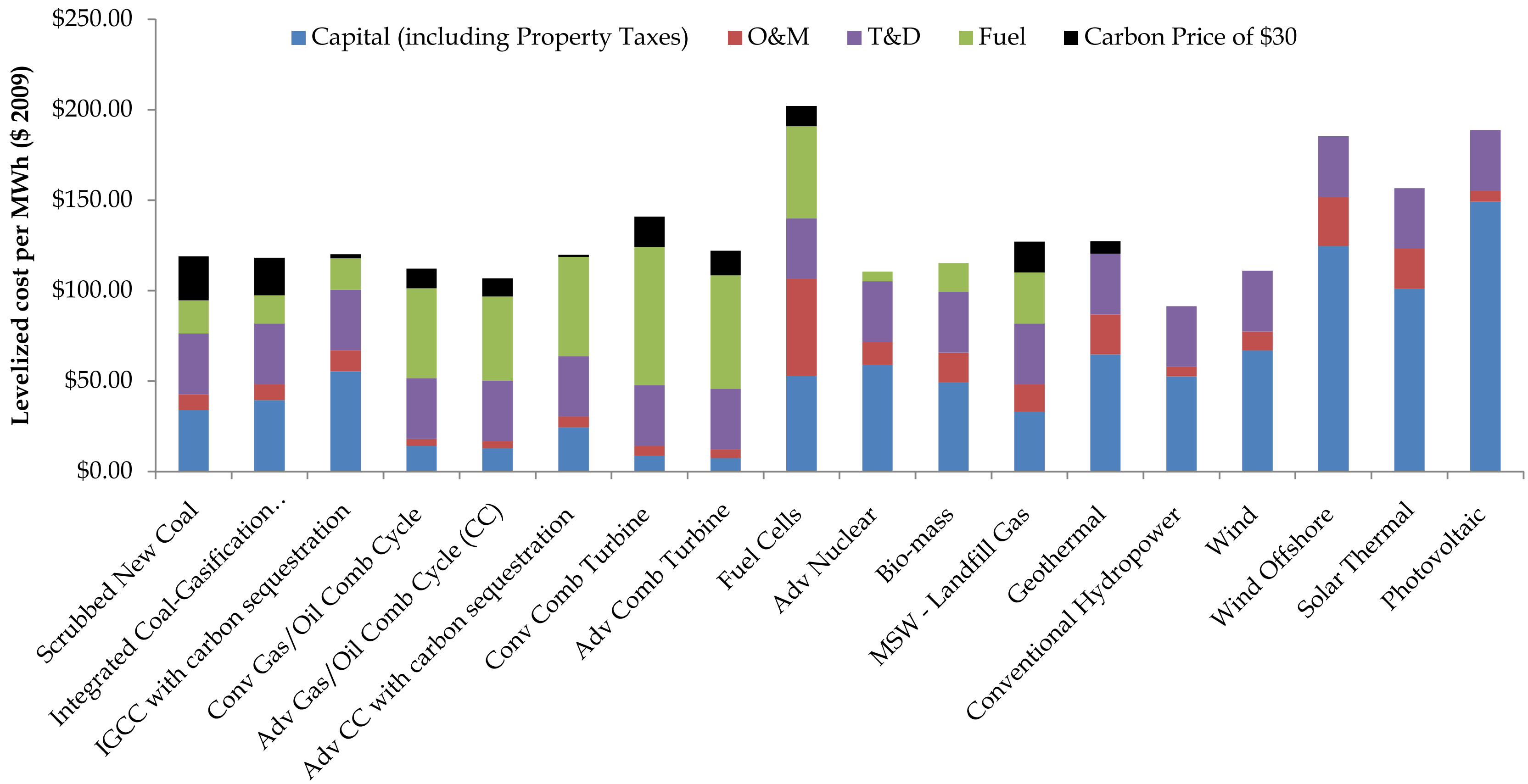
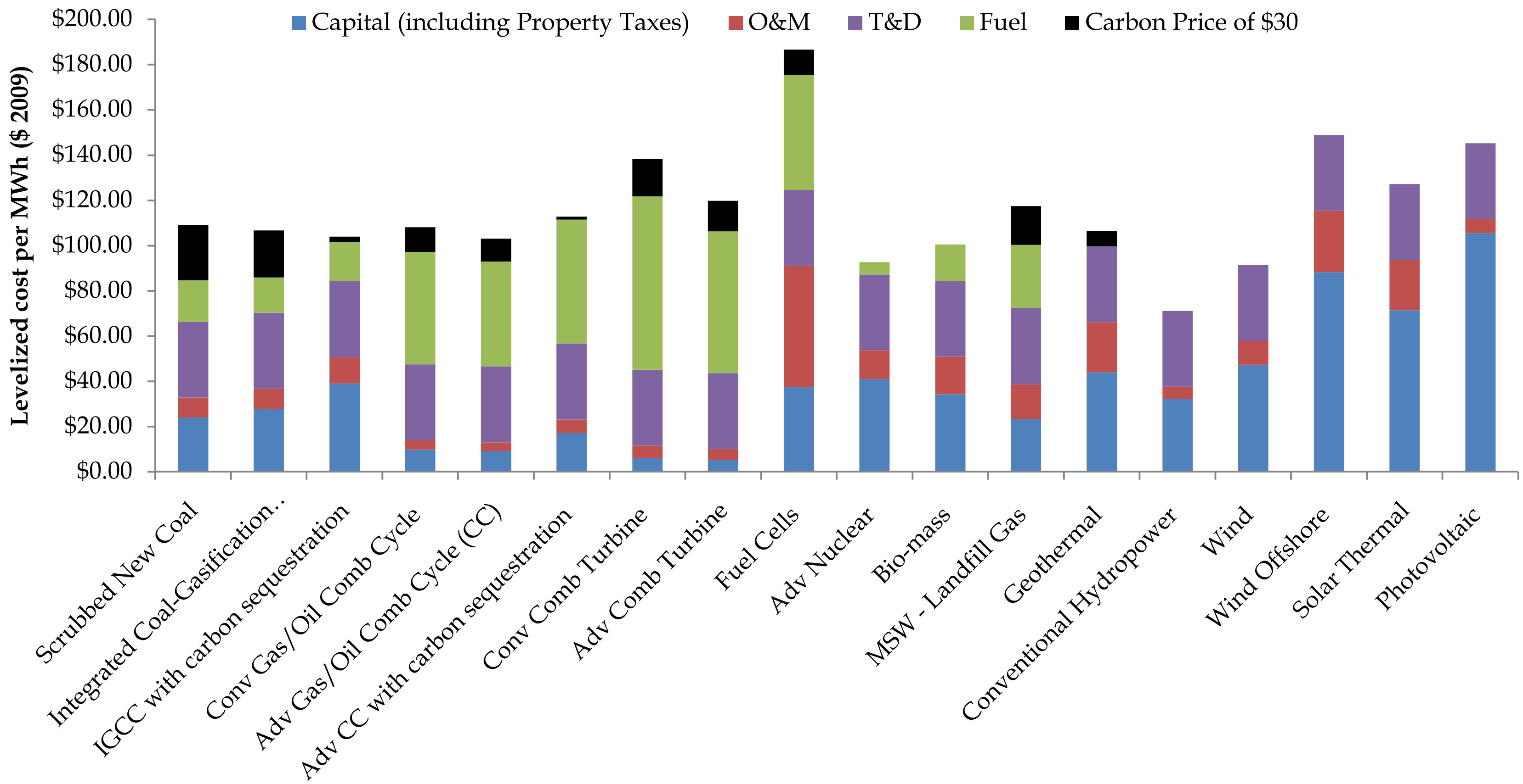


Figure 10: Levelized Cost of Delivered Electricity 2030: Falling Case assuming ITC remains at 30 Percent and Carbon Pricing



The introduction of a modest carbon pricing of $30 improves the cost competitiveness of solar technologies. In fact, the impact of a $30 carbon price means that solar technologies will be competitive with traditional forms of fossil fuel generation as long as the current federal ITC is extended beyond December 2016.

The important result is that modest carbon pricing means that solar (especially solar thermal) will be cost competitive by 2030 with natural gas technologies without requiring natural gas technologies to have a different cost trajectory (EIA rising capital cost case) whilst assuming solar capital costs are assumed to follow the EIA falling capital cost case.

4.2.1 Carbon Pricing Requirements for Solar to achieve Grid Parity by 2020

Below is a discussion surrounding the required carbon price to achieve grid parity under various capital cost and investment tax credit scenarios.

4.2.1.1 EIA Reference Capital Cost Scenario

By 2020 the levelized cost per MWh for new solar generation, under the EIA reference capital cost case, is forecast to be $228 for solar thermal and $292 for photovoltaic if all current incentives are included.[44] In contract, under the EIA reference capital cost case, new scrubbed coal generation plants are forecast to have a levelized cost per MWh of $100, whilst natural gas conventional combustion turbine generation is forecast to have a levelized cost per MWh of $113.

As noted previously, if carbon pricing is introduced it would raise the levelized costs of generation for fossil fuels. The required carbon price per ton of carbon (in 2009$) emitted to cause the levelized cost per MWh of scrubbed coal in 2020 to be equal to that of solar thermal (photovoltaic) is approximately $155 ($232). The required carbon price per ton of carbon emitted to cause the levelized cost per MWh of natural gas conventional combustion turbine

[44] ITC (which in 2020 will be 10 percent) and preferential property tax assessment.

generation in 2020 to be equal to that of solar thermal (photovoltaic) is approximately ($204) $320.[45]

If the investment tax credit was extended such that it remained at 30 percent[46] Then by 2020 the levelized cost per MWh for new solar generation, under the EIA reference capital cost case, is forecast to be $190 for solar thermal and $237 for photovoltaic.[47]

The required carbon price per ton of carbon emitted to cause the levelized cost per MWh of scrubbed coal in 2020 to be equal to that of solar thermal (photovoltaic) is approximately $109 ($166).[48] The required carbon price per ton of carbon emitted to cause the levelized cost per MWh of natural gas conventional combustion turbine generation in 2020 to be equal to that of solar thermal (photovoltaic) is approximately ($137) $220.

4.2.1.2 EIA Falling Capital Cost Scenario

By 2020 the levelized cost per MWh for new solar generation, under the EIA falling capital cost case, is forecast to be $206 for solar thermal and $260 for photovoltaic if all current incentives are included.[49] In contract, under the EIA falling capital cost case, new scrubbed coal generation plants are forecast to have a levelized cost per MWh of $95, whilst natural gas conventional combustion turbine generation is forecast to have a levelized cost per MWh of $112.

The required carbon price per ton (in 2009$) of carbon emitted to cause the levelized cost per MWh of scrubbed coal in 2020 to be equal to that of solar thermal (photovoltaic) is approximately $134 ($200). The required carbon price per ton of carbon emitted to cause the

[45] To increase conventional combustion turbine levelized costs to solar's levels requires a higher carbon price than scrubbed coal (even though the initial levelized cost of conventional combustion turbine is higher than that of scrubbed coal) because natural gas has a lower carbon content and lower heat rates than coal-fired generation.
[46] In 2017 it reverts back to 10 percent.
[47] There is no change in costs estimates for scrubbed coal and conventional combustion turbine.
[48] All carbon prices are in 2009$.
[49] ITC (which in 2020 will be 10 percent) and preferential property tax assessment.

levelized cost per MWh of natural gas conventional combustion turbine generation in 2020 to be equal to that of solar thermal (photovoltaic) is approximately ($168) $264.[50]

If the investment tax credit was extended such that it remained at 30 percent[51] Then by 2020 the levelized cost per MWh for new solar generation, under the EIA falling capital cost case, is forecast to be $173 for solar thermal and $212 for photovoltaic.[52]

The required carbon price per ton of carbon emitted to cause the levelized cost per MWh of scrubbed coal in 2020 to be equal to that of solar thermal (photovoltaic) is approximately $95 ($141). The required carbon price per ton of carbon emitted to cause the levelized cost per MWh of natural gas conventional combustion turbine generation in 2020 to be equal to that of solar thermal (photovoltaic) is approximately $109 ($178).

Table 7: Required Carbon Pricing (2009$) for Solar to Achieve Grid Parity

	2020 Reference		*2020 Falling*	
	Expected ITC (10 Percent)	**ITC Maintained at 30 Percent**	**Expected ITC (10 Percent)**	**ITC Maintained at 30 Percent**
Solar Thermal Grid Parity				
Scrubbed New Coal	$155	$109	$134	$95
Conv Comb Turbine	$204	$137	$168	$109
Photovoltaic Grid Parity				
Scrubbed New Coal	$232	$166	$200	$141
Conv Comb Turbine	$320	$220	$264	$178

[50] To increase conventional combustion turbine levelized costs to solar's levels requires a higher carbon price than scrubbed coal (even though the initial levelized cost of conventional combustion turbine is higher than that of scrubbed coal) because natural gas has a lower carbon content and lower heat rates than coal-fired generation.
[51] In 2017 it reverts back to 10 percent.
[52] There is no change in costs estimates for scrubbed coal and conventional combustion turbine.

5. Conclusions

There are numerous technologies that can be employed to enable utilities to continue to meet electricity requirements in Arizona, now and in the foreseeable future. Previous examination of unfettered market-determined levelized costs for new utility scale generation suggested that without significant deviations in forecast capital cost assumptions and/or fuel prices solar generation would not be cost competitive for the foreseeable future.[53]

However, when the current federal ITC and the reduced property tax assessment value offered in the State of Arizona are incorporated then the levelized costs for solar thermal and photovoltaic electricity generation do fall. The introduction of further government intervention in the form of carbon pricing will only improve the cost-competitiveness of solar generation and speed up the time frame within which solar will achieve grid-parity with traditional forms of electricity generation.[54]

Any additional improvements (that are non- overall capital cost related) such as the federal and state financial incentives offered for solar generation, higher carbon pricing and/or fossil fuel prices, improved capacity factors for solar generation will further improve the cost competitiveness of solar as well as improvement the timeframe with which solar achieves grid parity with other forms of generation.

Finally, the potential introduction of carbon pricing creates another cost uncertainty for traditional sources of generation, to go along with the uncertainty that already surrounds fuel costs, within the market place. If carbon pricing is finally introduced this will reduce some of the uncertainty as planners will know that carbon is being priced. But a significant amount of uncertainty will still remain as it may potentially be difficult to predict the carbon price through

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[53] See "*The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation", (2010)* Seidman Research Institute

[54] The greater the carbon price assumed and/or increasing the investment tax credit above 30 percent (or at least maintaining it at 30 percent after 2016) the quicker the time frame in which solar will achieve grid parity.

time. Thus, this uncertainty (which is currently not incorporated into the levelized cost analysis) can only improve the attractiveness of solar as an electricity generating technology.

Glossary

British Thermal Unit (Btu): A Btu is the quantity of heat required to raise the temperature of 1 pound of liquid water by 1 degree Fahrenheit at the temperature at which water has its greatest density - approx 39 degrees Fahrenheit.

Capacity factor: The ratio of the electricity that is feasibly expected to be produced by a generation plant over its life time considered to the electricity that could have been produced if the plant runs continually at full power over its lifetime.

Levelized Cost: The levelized cost of generation is the constant real price for this report that producers would need to receive if all the incurred costs of installing (including finance costs), operating and maintaining the plant are recovered over the life of the plant.

Nameplate capacity: The maximum amount of electricity (typically measured in megawatts) that an electricity generating plant can produce each hour. For example, if a plant has a nameplate capacity of 200 megawatts then theoretically the plant can produce 200 megawatts of electricity every hour.

Bibliography

Database of State Incentives for Renewable & Efficiency. (2009). *Federal Incentives*. Retrieved from http://www.dsireusa.org/

Energy Information Administration (EIA). (2009). *Electricity Cost Module.* Retrieved from www.eia.doe.gov/oiaf/aeo/assumption/pdf/electricity.pdf

Lazard. (2008). *Levelized Cost of Energy Analysis - Version 2.0.*

Pletka, R. e. (2007). *Arizona Renewable Energy Assessment.* Overland Park: Black & Veatch Corporation. Retrieved from http://www.bv.com/Downloads/Resources/Brochures/rsrc_ENR_AZ_RenewableEnergyAssessment.pdf

R.W. Beck, Inc. (2009). *Distributed Renewable Energy Operating Impacts and Valuation Study.* Phoenix: R.W. Beck, Inc. Retrieved from http://www.aps.com/_files/solarRenewable/DistRenEnOpImpactsStudy.pdf

Seidman Research Institute. (2008). *Infrastructure Needs and Funding Alternatives For Arizona: 2008-2032.* Tempe: Arizona State University. Retrieved from http://www.arizonaic.org/images/stories/pdf/AIC_FINAL_report.pdf

Seidman Research Institute (2010). *"The Market-Determined Cost of Inputs to Utility-Scale Electricity Generation"*, Tempe: Arizona State University

Seidman Research Institute (2010). *""Market Based Incentives""*, Tempe: Arizona State University

Seidman Research Institute (2010). ""*Regulations and Standards: Part I"*, Tempe: Arizona State University.

U.S. Bureau of Labor Statistics. (2009). Retrieved from http://www.bls.gov